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Title: Recent improvements in retrieving near-surface air temperature and humidity using microwave remote sensing

Abstract

Detailed studies of the energy and water cycles require accurate estimation of the turbulent fluxes of moisture and heat across the atmosphere-ocean interface at regional to basin scale. Providing estimates of these latent and sensible heat fluxes over the global ocean necessitates the use of satellite or reanalysis-based estimates of near surface variables. Recent studies have shown that errors in the surface (10 meter) estimates of humidity and temperature are currently the largest sources of uncertainty in the production of turbulent fluxes from satellite observations. Therefore, emphasis has been placed on reducing the systematic errors in the retrieval of these parameters from microwave radiometers. This study discusses recent improvements in the retrieval of air temperature and humidity through improvements in the choice of algorithms (linear vs. nonlinear) and the choice of microwave sensors. Particular focus is placed on improvements using a neural network approach with a single sensor (Special Sensor Microwave/Imager) and the use of combined sensors from the NASA AQUA satellite platform. The latter algorithm utilizes the unique sampling available on AQUA from the Advanced Microwave Scanning Radiometer (AMSR-E) and the Advanced Microwave Sounding Unit (AMSU-A). Current estimates of uncertainty in the near-surface humidity and temperature from single and multi-sensor approaches are discussed and used to estimate errors in the turbulent fluxes.

Recent improvements in retrieving near-surface air temperature and humidity using microwave remote sensing

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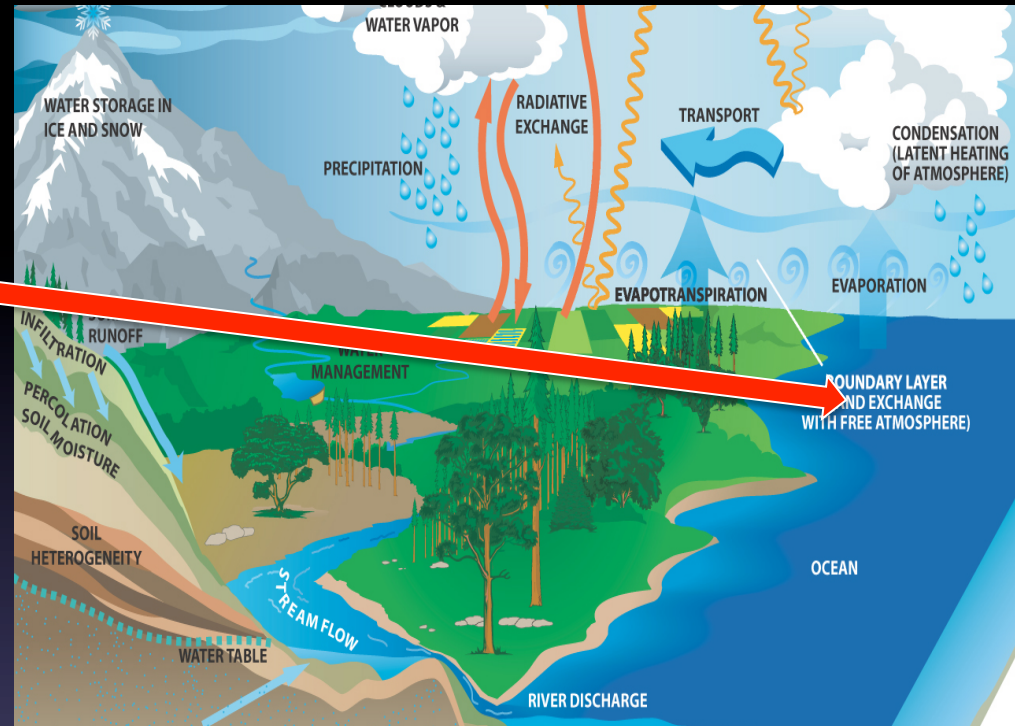
Outline

- ✓ Motivation
- ✓ Historical Approaches
- ✓ Recent Improvements
 - ✓ Algorithms & Sensors
 - ✓ SSM/I with SST, AQUA
- ✓ Current uncertainty estimates
- ✓ Outstanding issues



Global Energy and Water Cycle

- Turbulent oceanic heat and moisture transfer in the form of latent and sensible heat fluxes

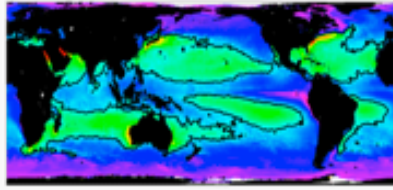


From NASA NEWS website

- Measuring globally requires estimating:
 - wind speed,
 - sea surface temperature
 - near-surface air temperature (TA)
 - specific humidity (QA)

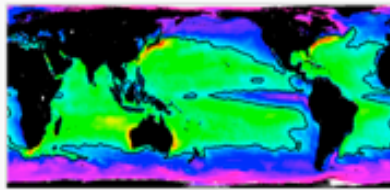
Flux Uncertainties

Seaflux v1 LHF



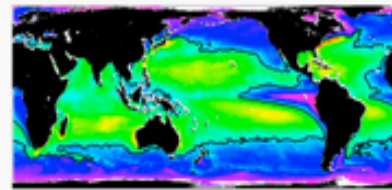
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OAflux v3 LHF



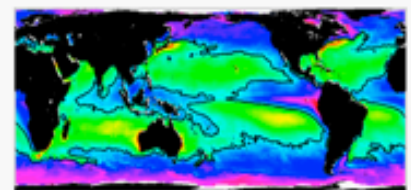
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Hoaps v3 LHF



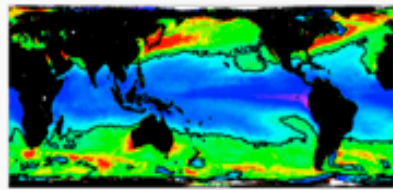
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Jofuro v3 LHF



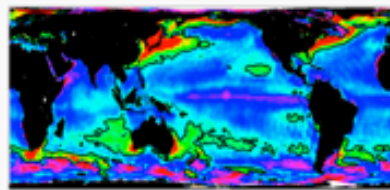
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Seaflux v1 SHF



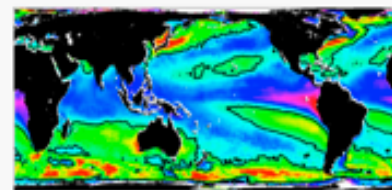
-10 -5 0 5 10 15 20 25 30 35

OAflux v3 SHF



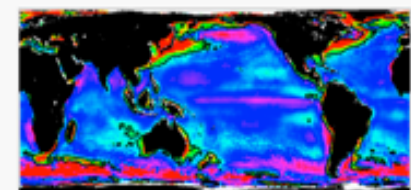
-10 -5 0 5 10 15 20 25 30 35

Hoaps v3 SHF



-10 -5 0 5 10 15 20 25 30 35

Jofuro v3 SHF



-10 -5 0 5 10 15 20 25 30 35

- SEAFLUX INTERCOMPARISONS
 - QA, TA differences play a major role in the differences between products.

Motivation

Historical
Approaches

Recent
Advances

Summary

Specific Humidity (QA)

- Use precipitable water (PW)
 - QA relationship and PW estimate from microwave radiometers (Liu, 1988)
- RT modeling suggests lower level moisture sensitivities to some SSM/I channels so regress WB500 with insitu QA (Schulz et al., 1993)
- Propagation of errors; fix by direct regression (Schluessel et al., 1995)

Air Temperature (TA)

- Use QA, estimate a RH of 80% and back out what TA should be (Liu, 1988)
- Estimate QA, SST, and wind speed and then make use of Bowen ratio (Konda et al., 1996)
- Derive SST-TA based on cloud classification (i.e. cloud heights/ boundary layer are influenced by stability) ; (Clayson and Curry, 1996)

(INDIRECT METHODS)



Algorithmic Improvements

$$TB = F(X)$$

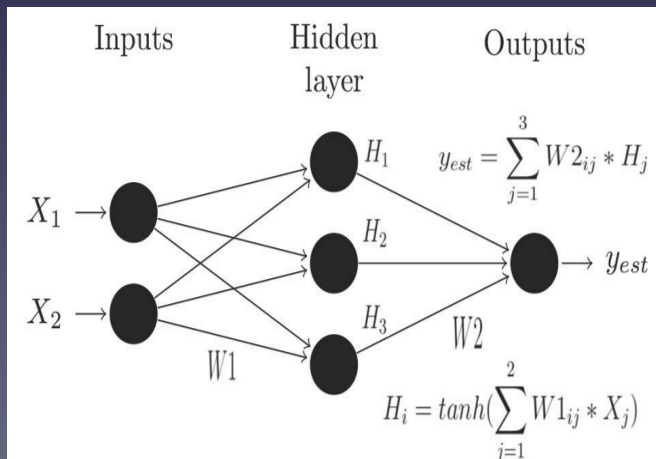
$$X = F^{-1}(TB)$$

GOAL: FIND $F^{-1}()$

LINEAR  NON-LINEAR

- stepwise linear regression (Jackson et al., 2006)

- Neural Network (Jones et al., 1999)
- Genetic Algorithms (Singh et al., 2006)
- Neural Network with first guess (Roberts et al., 2010)



$$X = F^{-1}(TB | X_{init})$$



Progression of Sensor Combinations

SSM/I –only
(Schulz et al, 1993;
Schluessel et al.,
1995; Bentamy et
al., 2003)

AMSUA–only (Shi,
2001)

AMSRE–only (Zong
et al., 2007)

Historical
Approaches

SSM/I + AMSUA
Combined (Jackson et
al., 2006, 2009)

AMSRE + NCEP₂
(Kubota and
Hihara, 2008)

Recent
Advances

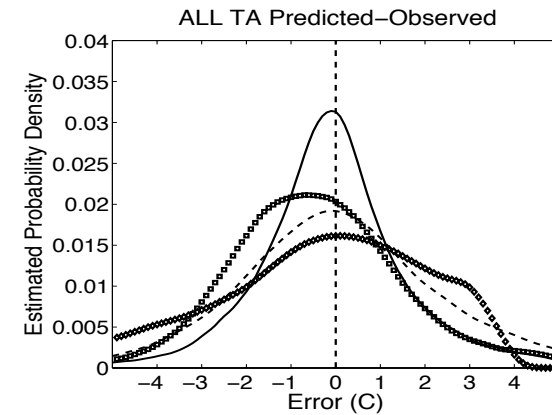
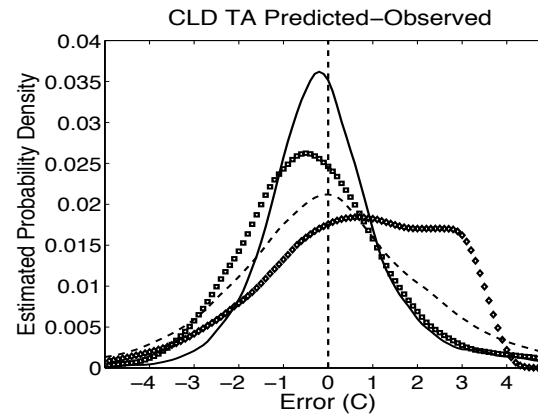
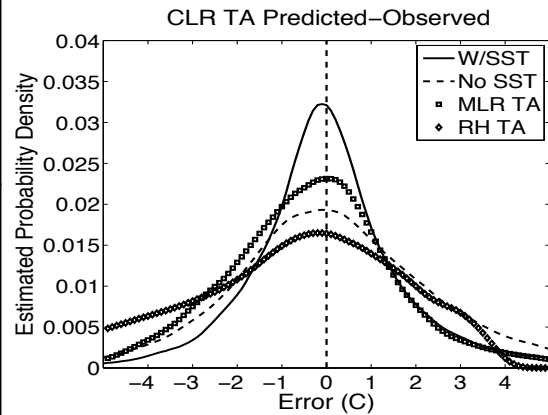
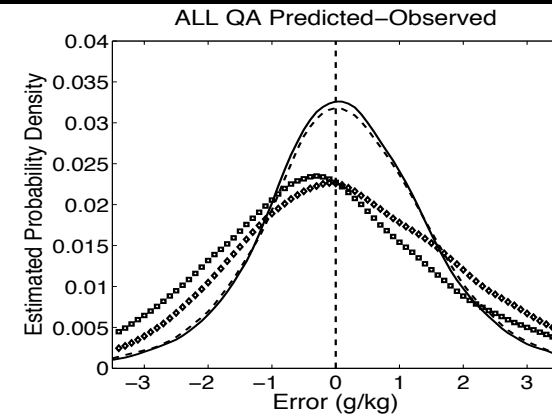
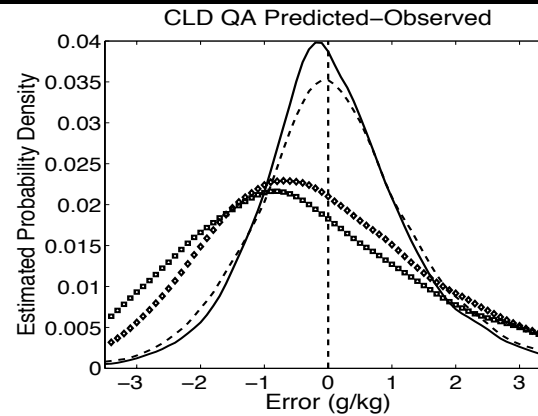
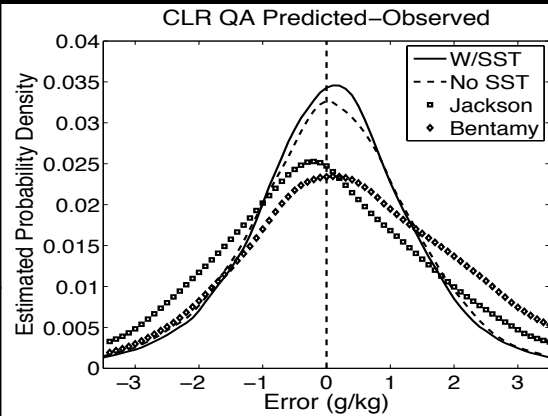
SSM/I + SST First
Guess (Roberts et
al., 2010)

AMSUA + AMSRE
(Roberts et al., in
preparation)

Summary



SSM/I + SST (Neural Network)



Distribution of errors; Clear and Cloudy conditions separated

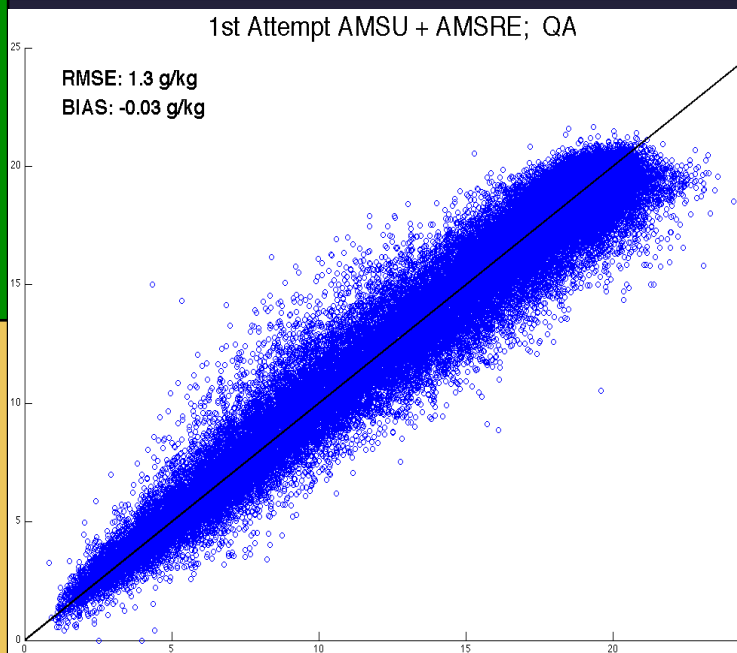
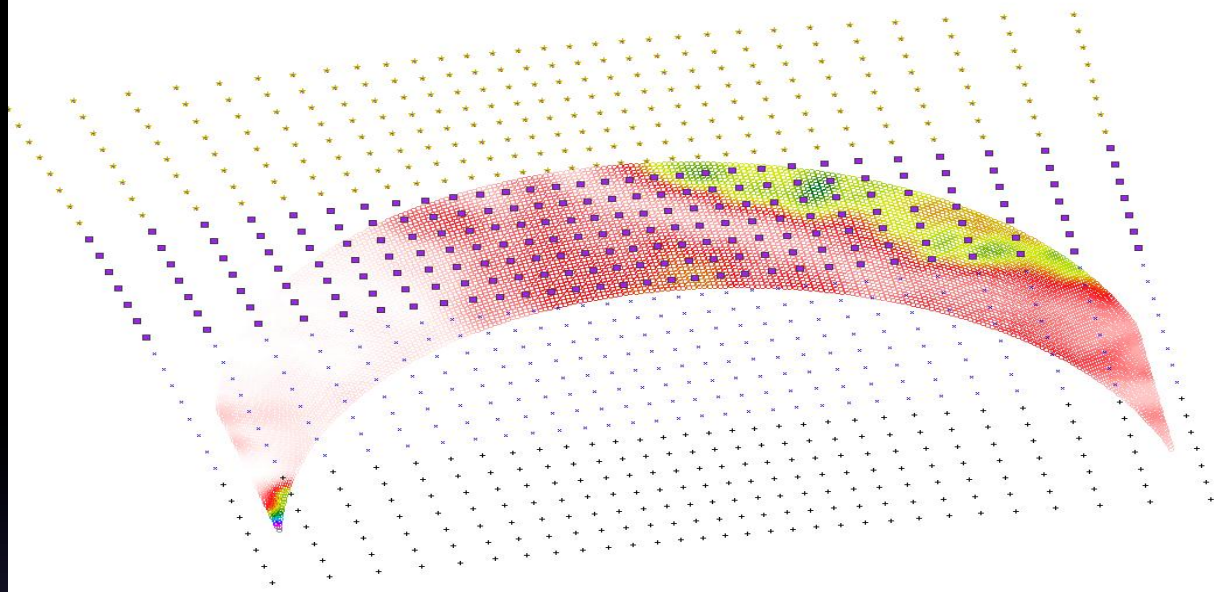
- The NNET is least biased and has narrowest distribution of errors.
- NNET significantly outperforms in cloudy conditions (more nonlinear RT)
- The air temperature retrievals rely heavily on the first guess SST



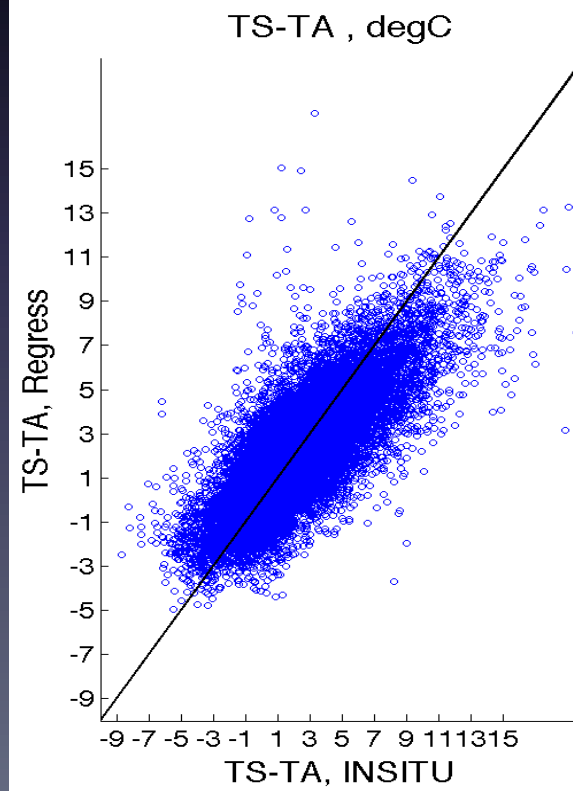
The AQUA Advantage

- AMSUA contains channels sensitive to lower troposphere
- AMSRE contains channels sensitive to PW, CLW, and SST

Example AMSUA, AMSRE Geometry; Contour=AMSRE



TS-TA improved by taking information from the surface and lower troposphere!



Motivation

Historical
ApproachesRecent
Advances

Summary

Current Levels of Uncertainty

Numerical
simulation of
errors for
typical
conditions

$C_e = 1.5 \times 10^{-3}$
 $U = 7 \text{ ms}^{-1}$
 $DQ = 4 \text{ gkg}^{-1}$
 $DT = 1.5 \text{ C}$

Systematic Error

- 0.1 g/kg (DQ)
- 0.1 m/s (U)
- 0.1 C (DT)

$\sim 8 \text{ W/m}^2$

Random Error (LHF)

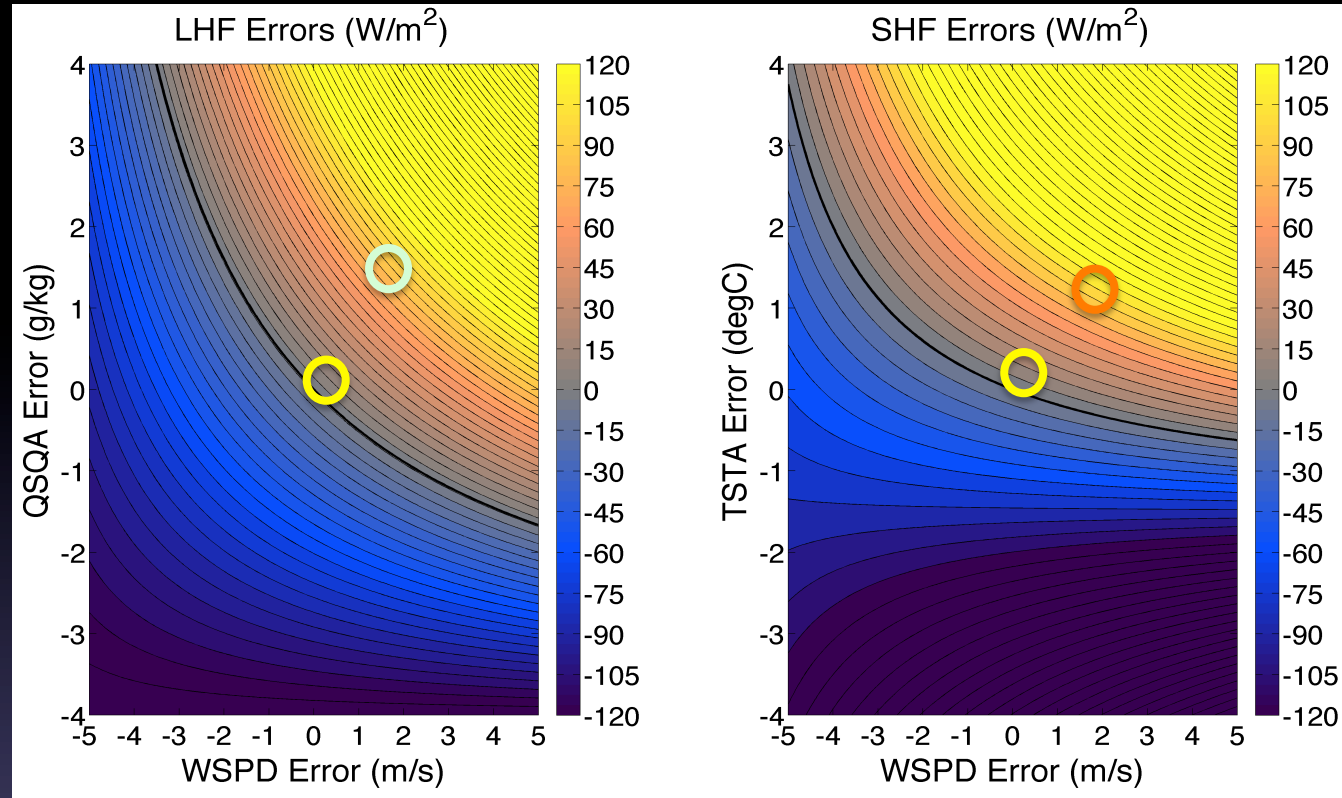
- 1.3 g/kg (DQ)
- 1.5 m/s (U)

$\sim 50 \text{ W/m}^2$

Random Error (SHF)

- 1.5 C (DT)
- 1.5 m/s (U)

$\sim 70 \text{ W/m}^2$



Summary

- Retrievals of QA and TA are progressing.
- Nonlinear methods may be more appropriate than standard least squares regression techniques
- Including information on the surface is important to improvements
- Current levels of uncertainty put systematic errors just under 10 W/m^2

Outstanding Issues

- How do we go from swath-level retrievals to gridded and interpolated products
- Can a blended TA/QA product be created from a combination of many sensors?
- What are the accuracy requirements needed for TA and QA retrievals?



Bibliography

Motivation

Historical
Approaches

Recent
Advances

Summary

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